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Status of the Labrador Pink Shrimp Resources, Divisions 2H and 2J

by

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Introduction

The Labrador shrimp (Pandalus borealis) fishery has been prosecuted for three successive years, 1977-79, the latter two of which were regulated by total allowable catch (TAC). Levels of TAC were based on information presented by Sandeman (1978) and Parsons et al. (1979). With only three years of information it is still difficult to determine any trends in the fishery and response of the resource to fishing pressure. Data collected to date both from the fishery and research surveys, do supply valuable information which help place the preliminary recommendations of potential yield in perspective.

An observer programme, initiated in 1978 to obtain information from the commercial fishery, was continued in 1979 and provided details of catch, catch per unit effort, by-catch and discarding practices. Research surveys were conducted in areas of shrimp abundance off Labrador and northeastern Newfoundland in July-August and November, 1979, from which additional information on shrimp distribution and biomass was collected.

This assessment collates available information from both sources and incorporates interpretive biological information not only from the Labrador 'stocks' but from other areas as well. Fisheries for this species have provided

two undeniable conclusions: 1) that techniques for traditional resource assessments are extremely difficult to apply and 2) that shrimp resources can experience dramatic and imperceptible declines. These factors must be considered when interpreting the following information.

Management Areas

Recent analysis has treated the most productive areas of shrimp abundance as separate stocks. Three geographically isolated marginal troughs or depressions in the Labrador shelf have been shown to support significant quantities of shrimp (Fig. 1). The Cartwright and Hopedale Channels have been fished most extensively from 1977-79 but the Hawke Channel, the area which first showed commercial potential in the mid 1970's, has not produced economical catch rates in recent years.

Migration of animals among these areas is not considered to be substantial and recent information (to be presented in later sections) indicates differences in natural mortality rates and recruitment. For these reasons the areas are again treated as separate utilization zones.

Fishing Pattern

Fishing pattern for the fleet was consistent in its inconsistency with other years. In contrast to 1977 and 1978 (Parsons et al. 1979), fishing proved much more favourable in the Hopedale Channel in the early 1979 season (Fig. 2). As a result records for catch and effort were more complete for this northern area in the early season than for any of the other years. By contrast, very little effort was directed to the Cartwright Channel (Fig. 3) despite isolated catches which surpassed 1978 maximal levels. Data for this area were extremely lacking in the early season for the first time in three

years. The Hopedale Channel was closed on September 3 and vessels were forced to move south to the Cartwright Channel where, by this time, about one-third of the TAC of 800 m tons had been removed. Vessels took the remaining catch in less than three weeks and this area was closed on September 23.

Catch and Catch Per Unit Effort

Fig. 2 and 3 support the contentions that daily catch rates experience wild fluctuations and that there is a seasonal decline in abundance of shrimp. Data from a previous study (Parsons et al. 1979) indicate that this decline may be due to other factors beside fishing pressure. Some corroboration may be evident from the limited information for the Cartwright Channel in 1979. A decline in abundance may be interpreted even though effort was very low. No data were available from late season to indicate any abundance increase for either area.

Catch rates in the Hopedale Channel in June approached record levels experienced in late December 1978. These rates declined sharply and steadily from around 1400 kg per hour in June to 300 kg in late July, then leveled off (with considerable fluctuation) until the area was closed in early September. Comparing catch rates in 1979 with those obtained in the previous years (Table 1) there appears to be a decrease from 546 kg per hour in 1978 to 470 in 1979. The latter is heavily weighted by considerable effort in August when catch rates were low. Unweighted rates indicate relative stability in abundance with 560, 585 and 542 kg per hour from 1977 to 1979, respectively.

Data for the Cartwright Channel are lacking in the early season but a decline in 1979 catch rates is suggested (Fig. 3, Table 1) which appears similar to that described above. By August rates had declined to 275 kg per hour (low enough for the fleet to remain in the northern area) and levelled

off at 200 kg in September when the fleet moved south after closure of the Hopedale Channel. Total CPUE figures in Table 1 tend to exaggerate any decline in abundance from 1977 to 1979. Most effort was expended in September 1979 when catch rates were at the lowest level - the total figure being weighted accordingly. The entry for June 1979 is based on very little effort and has to be considered unreliable. July to September in all three years provide a basis for comparison, but, again, weighting factors in 1978 and 1979 are misleading. Unweighted averages for July to September indicate an overall decrease in CPUE of 33% from 1977 to 1979 (571, 505 and 380 kg per hour respectively). These observations do not take into account that patterns of availability may vary between years. It is also worth noting that the high and low catch rates for 1979 fall between the range of high and low levels for 1977 and are similar to those for 1978. Accepting that there is a decrease in abundance it can be postulated that the total mortality (fishing and natural) experienced in the Cartwright Channel sufficiently outweights the contribution to the stock size through somatic growth and recruitment. The magnitude of this imbalance is all important and extremely difficult to quantify.

The Hawke Channel remained virtually unfished in 1979 with only 3 m tons being reported. Although the TAC for this area was increased to 1700 m tons for 1979, vessels failed to obtain economical catch rates. The effort involved in searching for suitable catches was very low.

Biomass 1979

A research cruise to the Labrador area in July and August provided data for the estimation of minimum trawlable biomass in the three channels (Table 2, 3 and 4). The swept-volume method was again employed using a Sputnik 1600 shrimp trawl with an estimated horizontal opening of 22 m (Carrothers, pers. comm).

A 13 mm liner was used to reduce selectivity. The net was towed at 3.0 knots at predetermined depths along lines which adequately covered the area surveyed.

The 11,520 m tons estimated for the Hopedale Channel (Fig. 4, Table 2) is 28% higher than the higher option of mean biomass (9000 m tons) used to derive the 1979 TAC. Available biomass at the time of the survey was quite high and indicates that such surveys should take place early in the season when both shrimp abundance and weather conditions are obliging. The 9000 ton estimate was derived from commercial data using a wingspread of 27.4 m. If the wingspread is actually less ($\sim$ 22 m) then the estimates of biomass in the two years are remarkably similar. Thus, the stability in catch rates and biomass may be somewhat supportive. Both biomass estimates come from periods of high abundance (Dec. 1978 and July 1979) with no fishing occurring between the two.

Virgin biomass for the Cartwright Channel (Table 3, Fig. 5) was estimated around 4000 m tons (Parsons et al. 1979). Because of the limited fishable area and observed decline in CPUE from 1977 to 1978 it was decided to keep the TAC at a level of 800 m tons. The 1979 biomass estimate of 2,106 m tons indicates a decrease of 47% from the virgin level. This is also supportive of the CPUE data which suggests a decrease in abundance from 1977 to 1979.

Data from a 1975 survey indicated a virgin biomass for the Hawke Channel (Table 4, Fig. 6) around 5000 m tons. The 1979 results show a reduction to approximately one-half that level (2429 m tons). There are no sufficient commercial catch data to corroborate this decrease. If a decrease in stock size has actually occurred then it has done so naturally. Fishing mortality is not considered a factor in this area.

Collection and analysis of data for the 1979 biomass estimates have revealed some interesting facts regarding methodology which are worthy of note at this time. Diel variability in catch rate is well known to occur for

stocks of P. borealis. To reduce some of this variability an attempt was made to correct for vertical migration by the application of hourly conversion factors. The methods were similar to those described by Parsons (1979). Peak catch periods were obvious between 1200 and 1400 hours with considerable reduction from 2000 to 0600. Conversion factors were obtained by fitting curves through data points spanning a 24-hour cycle. When applied to the biomass data serious anomalies become obvious. In many cases within strata the survey results did not fit the diel variability data i.e. maximal correction factors were applied to maximal catches. This resulted in artificially high biomass estimates with increased variance. If catches are sufficiently depressed at night then the ommission of these data should result in considerably higher biomass estimates. This was not the case in all areas surveyed. The resulting hypothesis is that there is sufficient within stratum variation to completely negate the effects of diel variability. Data from the 1979 survey were not sufficient to test this hypothesis but the problem should be investigated in future surveys. For the purposes of this presentation, no correcton has been made to catch data to account for diel variability.

Heavy ice in areas north of the Hopedale Channel provided extra time to revisit areas surveyed two or three weeks earlier. Considerably less sampling was done on the return visits but changes in distribution were detected over this relatively short period. In early July shrimp in the Hopedale Channel were concentrated in the northern part of the area (Fig. 4) in depths greater than 385 m. Two to three weeks later there was evidence to suggest that concentrations were not so pronounced in the northern area and more shallow water was preferred (between 240 and 460 m). Conversely, in the Hawke Channel shrimp were dispersed throughout a depth range of 340 to 540 m but two weeks later there was a higher proportion evident in water deeper than 420 m.

These observations suggest that survey timing may be extremely important and that a given area should be surveyed within the shortest possible time. They also enhance the variability problem within any survey time-frame in suggesting that shrimp are capable of changing distribution patterns over sufficiently short intervals.

Extreme variability encountered by using the swept volume methods, at least in the Labrador Channels, impose severe limitations on the application of such results. However, with the limited data base available at this stage of fishery development they must be used in conjunction with commercial catch rate data in an attempt to monitor the stocks.

Size Distribution

Research

Size distribution of shrimp measured to 0.5 mm carapace length are presented in Fig. 7-10. The survey was conducted at a time before the ovigerous period for females in this area. The research trawl was lined with 13mm netting to reduce the selectivity problem, however, comparison of frequencies and catch curves (see the following section) from commercial and research trawls indicate little difference between the two. It may be possible that considerable selectivity occurs before the catch enters the codend. If this is so then modes below 20 mm at least will show considerable bias in their apparent values (Axelsen et al. 1979).

In the Hopedale Channel (Fig. 7) modes were evident at 8-9, 13-15, 18-19, 21-22, 24 and 27-29 mm. At face value these peaks may represent the 0 to V+ age groups respectively. If selectivity is not a problem then peaks observed at roughly 17, 20 and 24 mm in 1978 (Parson et al. 1979) can be said to have grown to 21-22, 24 and 27-29 mm respectively. Should the small-meshed liner

not significantly change selectivity then the 17 mm group in 1978 was probably much smaller (Axelsen et al. 1979) and is represented by the 18-19 mm group (or less) in 1979. Then the 20 mm group in 1978 probably split into two modes, one fast-growing which changed sex to female (24 mm) and one slow-growing which remained as males or transitionals (21-22 mm). This phenomenon has previously been presented by Rasmussen (1969). The 21-24 mm group would then be representive of age groups III and the final mode would be IV+. The relative abundance evident from Fig. 7 indicates higher densities occurring in the deeper strata to a limit of 570 m.

Fig. 8 presents size frequency by depth interval for the Cartwright Channel. Modes are evident at 13, 17-18, 24 and 28 mm. Another mode around 20-21 mm can be interpreted from some of the depths but its prominence is quite obscure. The overall picture is quite similar to that of the Hopedale Channel and, depending on the aforementioned selectivity problem, the obscure mode is either a not-so-successful year-class or a lesser degree of modal bifurcation. Fig. 9 provides information from a rather abortive survey attempted in November in the same area. Most of the samples were taken at night but do, at least, show peaks in the same general range as those for July. Greater densities are observed in the deeper strata in July than in November. This would be expected as there is a general concensus that ovigerous animals migrate to shallower water sometime before hatching time.

Frequencies of length by depth-interval for the Hawke Cannel (Fig. 10) show evidence of a mode around 13-14 mm and more prominent modes at 16-19 and 24 mm. These also correspond reasonably to those evident for the two more northerly Channels but one size-group (20-22 mm in the other areas) does not show prominence at any depth. In addition there is a distinct scarcity of animals in the group greater than the 24 mm mode and their occurrence is

hardly noticable compared to the other two areas. Distribution is limited mainly to depths between 340 and 540 m.

Commercial

Data from the commercial fleet by month for the Hopedale Channel show a unimodal distribution (22 mm) in the first two months of the season when catch rates were highest (Fig. 11). Depths fished at this time were usually between 420-500 m and these distributions correspond reasonably well to the research data for the same depths. The lack of detail in the commercial sampling probably results from the larger sample size and combination of measurements to 1.0 mm but evidence of modes at 18, 24 and even 28 mm can be interpreted. The distribution changed with the decline in catch rates and in August and September greater proportions of the 18-19 and 24 mm modes occurred.

Modal progression from 1977 to 1979 is presented in Fig. 12. The 19 mm mode in 1977 is very likley smaller if considering selectivity and probably represents age class II. This group appears as the 20-21 mm mode in 1978 and 24 mm mode in 1979. If there is a modal split then the broad range of sizes between modes of 20 and 24 mm represents age class III. The modes at 19 mm in 1979 resulted from animals in the 16-18 mm group in 1978. This increment should be increased due to selectivity. The mode at 24 mm in 1978 is probably represented at 27 mm in 1979.

Commercial sizes from the Cartwright Channel in 1979 indicate that reports of less discarding in this area may be valid. Sizes in August and September, the period when effort was increasing, are modal at 24 mm (Fig. 13). The mode at 18 mm is only evident is samples from June. Fig. 14 suggests that growth in this area is similar to that for the Hopedale Channel with the 19 mm mode in 1977 progressing to 20-21 mm in 1978 and 24-25 mm in 1979. The possibility

of one year-class producing two modes (as described for the Hopedale Channel) is also evident here. Other size groups are obscured especially in the 1979 data.

Estimates of Total Mortality (Ż)

In the absence of reliable aging methods or data the task of determining mortality rates increases in difficulty. The analysis of catch curves had its origin based on length rather than age (Ricker 1975) and with due caution this technique can be used to interpret some trends in mortality. The main drawback that the method affords is that length of the recruited age groups increases in a linear fashion with age. Evidence exists (Kitano and Yorita, 1978; Ito 1976; Fox 1972; Sandeman, pers. comm.) that for recruited length groups the growth curve is sufficiently straight to assume a growth increment per year. The records of length are reasonably accurate and are not heavily influenced by subjectivity. Aging, on the other hand, is estimated using various techniques that involve considerable subjectivity. The length statistic is often excluded in favour of age as a direct means of parameter interpretation. However, it has been stated that for shrimp, sex change is determined by size rather than age (Hoffman 1972; Ramsussen 1969).

The problems involved with aging for Labrador shrimp as described previously do not allow for an easy interpretation of length increments but in observing differences between modes for a single year and following modes in successive years it appears that the increase fluctuates in the range of 3 to 4 mm per year.

Recognizing the above assumptions, catch curves were constructed from two sources: commercial data for the Cartwright and Hopedale Channels for 1979 and research data for all three areas in 1979. All sampling from the commercial catches were weighted to catch, monthly catch and combined to represent the total catch for which records are available. It is assumed that these records

reflect the complete trend in catches for the year. Research samples were adjusted to catch and then adjusted to biomass per stratum. Results for each stratum were summed to give a representation of biomass (numbers) at length. Plotting these data (Fig. 15-19) catch curves are generated which resemble the classical examples with a steep left limb and a dome-shaped upper portion but differs in that the right limb is also very steep-immediately indicating high mortality rates. Good r^2 values from regression analysis are obtained from all data points along the right limb but inflection is evident in the line around 28-29 mm. The increase in slopes beyond this point is probably due to two factors. Firstly, there may be differential mortality with age (length) and, secondly, growth of the very oldest animals is probably less than that of the younger. In any event the steeper slope is characteristic of few individuals relative to the total. The line between 23-24 and 28-29 mm represents at least one year's mortality (1978), is more characteristic of the fully recruited sizes[1] and comprises a substantially larger portion of the total numbers. The lower rate should also be more appropriate for size groups approaching full recruitment.

The similarity of the commercial and research figures does not indicate any reasonable difference in selectivity between the two trawls. The research gear does catch smaller individuals and shows modes at sizes that can reasonably be interpreted as age-groups (recall the previous section). There may be an interacton of selectivity and availability in this case.

There is good agreement in the slopes of the lines from both sources for the Cartwright and Hopedale Channels. Assuming a similar natural mortality rate, fishing mortality is also similar. The average slope for both areas and source (N = 4) is -0.46. This figure gives a per mm rate and to adjust it to the annual rate it is necessary to multiply by the estimated increment (3-4 mm per year) resulting in estimates of Z between 1.38 and 1.84.

[1] Fully recruited size for commercial gear with 38-42mm mesh size is considered to be around 23mm (cl) as interpreted from Labonté and Fréchette (1978).

Mortality for the Hawke Channel is only estimated from research (1979) data. The difference in rates at length is not so obvious and the slope of the line between 24 and 28 mm is extremely steep (-0.79) in comparison to the other areas. Using this part of the line to estimate recent mortality (1978) and the range of increments indicated from research surveys in 1978 and 1979 (3-4 mm per year) $\bar{z}$ is estimated between 2.37 and 3.16. Since there is no significant fishing in the area $\bar{z} = M$. Although these rates reflect very low survival (4 to 9%) length frequency data have already shown very few animals beyond the 24 mm mode. Ignoring actual values the rates are almost twice as high as those for the other two areas which are fished commercially.

Yield per Recruit

Baranov's method of the estimation of equilibrium yield as described by Ricker (1975) permits the use of length as a measure of time. Again, as with catch curves, there are severe limitatons of the method. 1) Length increments should remain constant over the main range of commercial sizes. This has been dealt with in the previous section. 2) Weight must be proportional to the cube of the length. Isometric growth has been demonstrated for P. borealis in all three Labrador Channels (Parsons, unpublished). 3) There is no flexibility in respect to mortality. In deriving the 1979 TAC it was the consensus that a natural mortality rate of 0.7 should be a reasonable estimate for fully recruited sizes (ages). This is the most serious limitation of the model. 4) Shrimp do not suddenly become catchable at a specific size. Mean selection length of 17.0 mm (cl.) has been interpreted for gears in the 38-42 mm mesh size range from data presented by Labonté and Fréchette (1978) as a means to minimize this problem.

Changing the annual growth increment (d) has a profound effect upon the resulting yield per recruit. Therefore, the model has been run with values included in the range presented earlier (Fig. 20). The exercise only considers changes in levels of fishing intensity since the 40 mm mesh size provides both economical catch rates and minimal discards. The yield curves are asymptotic with no realistic F_{max} values. $F_{0.1}$ can be interpreted over a relatively wide range because of the gentle bend in the curve but have been calculated around 0.60, 0.75 and 0.90 for d values of 3.0, 3.5 and 4.0 mm per year, respectively. Using an M of 0.7 for both Hopedale and Cartwright Channels, recent levels of fishing (1978, at least) may have been (with one notable exception) within a reasonable range of $F_{0.1}$ (Table 5). The worst situation is where d = 4 and the recent F values is approaching twice the $F_{0.1}$ level. The effect of higher natural mortality is also evident from the data in Table 5. Increasing M has three effects, it decreases the yield per recruit, increases $F_{0.1}$ and decreases the estimate of fishing effort. The results achieved from catch curve analysis in the Hawke Channel indicate a distinct possibility that M can be considerably higher than 0.7.

With the present variation in estimates of annual growth increments and lack of data on estimates of M, the yield per recruit model has little practical application. The only interpretation to be made is that the $F_{0.1}$ area is fairly broad and there is a possibility that present levels of fishing effort in the Cartwright and Hopedale Channels fall close to this range. The method can be of real value and is quick and easy to use. Updates are encouraged when more accurate input becomes available.

Observations on By-catch, Discards and Weight Conversions

Information collected by observers onboard commercial vessels allow some assessment of the by-catch situation and discarding practices of the fleet. Main by-catch species of commercial value are turbot and cod, the former comprising in 1979 roughly 7% of the total catch of commercial species and cod, only 1.3%. Higher proportions of these by-catch species were observed in the Cartwright Channel in 1979 with percentages of 13 and 3 for turbot and cod, respectively. Discarding of these species vary with vessel and range from total discard to total retention. Redfish do not contribute significantly to the by-catch problem. Considerable quantities of small turbot are known to occur in shrimp catches in this area. The situation is presently under investigation by the CAFSAC Groundfish Subcommittee. Wolffish, skate, grenadier and American plaice occur quite frequently as by-catch as well.

Discarding of small shrimp proved to be a controversial subject in 1979. Data collected from the fleet indicate discards as high as 26% for three days in the Cartwright Channel. Individual sets have discards in excess of 50% but for some 862 tons for which observations are available, approximately 8% were reported as discards. Considering each area separately, 4% was reported for the Cartwright Channel and 9% for the Hopedale. Efforts should be increased to lower these percentages to the zero level reported from at least three vessels fishing the Labrador in 1979.

In considering the 1979 TAC it was pointed out that there is weight loss due to cooking shrimp. As vessels process their catch onboard in many cases it was felt that a conversion factor was necessary to more accurately monitor the actual catches. During research cruises to the Labrador, Gulf of St. Lawrence, and Davis Strait in 1979 data were collected to provide this factor. Regression through the origin (Fig. 21) of fresh weight on cooked weight

resulted in a conversion factor of 1.11 (r = 0.998). This represents a 10% weight loss and is sufficiently consistent with independent observations in the 10-12% range.

Hydrography

Favourable water temperature has been a concern for the survival of populations of Pandalus borealis. Parsons et al (1979) observed no evidence of a cooling trend in these areas over recent years. Data collected in 1979 suggest bottom temperatures in the range of 2 to 3.5°C in areas of shrimp abundance. These are consistent with data from years previous and support the observation presented in the earlier report.

Discussion

Early observations of the shrimp stocks off Labrador provide information which, although not yet quantifiable, can be reflected upon based on the known biological characteristics of the species. It has already been stated that shrimp populations can and have demonstrated sudden declines. Information for the Hawke Channel indicates this possibility if mortality of the spawning stock continues at a high level and recruitment is significantly reduced. If there has been a split in the growth of a single year-class in the two northern channels it has not obviously occurred in Hawke Channel. One advantage of this phenomenon would be to enable a population to respond to pressures of mortality by changing to females earlier than under less stressfull conditions. With apparent high mortality of ovigerous animals in this area it would be advantageous for a transition to females at an earlier age as a built-in mechanism to preserve spawning stock. If the absence of a mode indicates failure of a year-class rather than a change in maturity, then factors must be operating in the southern area which are different from those in the north.

The controversial 20-22 mm mode decreases in prominance from north to south. When considering the above alternatives it may serve as an indicator of the relative 'health' of the stocks.

Sufficient evidence exists to cast doubt upon the long-term stability of shrimp stocks, in general. The animal is a protandric hermaphrodite and the hermaphroditic nature has been described as particularly advantageous in situations where populations are periodically reduced to very few individuals (Smith 1975). Characteristics of the stock in the Hawke Channel may indicate movement in that direction or the potential for it. Considering the delicate balance of biological and environmental factors it may be somewhat risky to rely upon projected long-term yields of pink shrimp in the Labrador areas. This has particular impact in the field of industrial development.

Conclusions

Favourable conditions are apparent in the Hopedale Channel from catch rate and biomass data. Recruitment levels comparable to those of other years are evident in the 18-19 mm mode. The 1979 TAC was based on a mean biomass estimate of 9000 tons but the horizontal opening of the fishing gear was considered to be 27.4 m. If the opening was more like 22 m as indicated in recent work this estimate would be 11,200 tons and in good agreement with the July 1979 survey. An adjustment of the TAC to approximately 4000 m tons would then be in order.

Because abundance levels seem relatively stable in this area and mortality of fully recruited animals appears to be significantly less then that of the Hawke Channel it is advisable to continue the 1980 TAC at the 1979 level (3200 m tons) or certainly not beyond the adjusted 4000 m tons indicated above.

Although mortality for the Cartwright Channel appears similar to Hopedale, abundance indices, both relative and absolute, indicate an overall decrease from the 1977 levels. Recruitment indicated in the 18 mm mode for June did not show later in the season in commercial catches. In 1979 the TAC was held to a level lower then the estimated MSY of 1400 m tons because of the decrease evident in 1978 and considering the restricted fishable area. The observed decrease seems to be in the order of 33 to 47%. Applying these percentages to the original MSY, catch levels should be in the order of 742-938 m tons. Therefore, the TAC for 1980 in this area should also remain at the 1979 level (800 m tons). Records indicate that catches only reached the estimated MSY in 1978 suggesting this estimate may have been too high or population growth has been less than ideal in recent years. The 1979 catch has been kept reasonably close to the TAC and the result of better monitoring procedures should be borne out in the 1980 catch rates.

Advice on TAC for the Hawke Channel becomes more difficult under existing conditions. Reduction in biomass from the 1975 level, extremely high natural mortality rate estimates and the lack of success of the commercial fleet in finding suitable concentrations all indicate a depressed condition of the stock. A decrease in biomass of 50% would suggest that the TAC be reduced accordingly to 850 m tons. Any level of catch set for 1980 must be considered entirely theoretical, recognizing the fact that catch rates, as in past years, will not be sufficient to attract any effort from the commercial fleet. In allocating quotas for Labrador shrimp in 1980 it is suggested that only tonnages for areas with known commercial viability be used. TAC's for 'unproven' areas will hopefully attract some preliminary investigation of the actual commercial potential.

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Table 1. Catch per hour fished 1977-1979. Values for each month determined from vessel logs.

Month	1977 Catch (Kgs)	1977 Effort (Hrs)	1977 CPUE (Kgs)	1978 Catch (Kgs)	1978 Effort (Hrs)	1978 CPUE (Kgs)	1979 Catch (Kgs)	1979 Effort (Hrs)	1979 CPUE (Kgs)
				H O P E D A L E C H A N N E L					
June	-------	-----	---	-------	-----	---	426,390	450.5	947
July	-------	-----	---	138,322	179.0	773	906,784	1,443.0	628
Aug.	109,502	179.3	611	92,097	168.5	547	836,384	2,541.3	329
Sept.	254,408	436.8	582	69,605	214.2	325	111,813	420.8	266
Oct.	480,613	1,419.6	339	731,697	1,465.9	499	-------	-----	---
Nov.	657,580	929.5	707	853,954	1,643.5	520	-------	-----	---
Dec.	-------	-----	---	339,327	401.0	846	-------	-----	---
Total[1]	1,502,102	2,965.2	507	2,225,002	4,072.1	546	2,281,371	4,855.6	470
Total[2]	1,550,000	2,965.2	523	1,847,000	4,072.1	454	2,822,000	[3]	
				C A R T W R I G H T C H A N N E L					
June	-------	-----	---	-------	-----	---	5,150	23.5	219
July	287,640	406.0	708	155,811	325.0	479	147,442	224.0	658
Aug.	536,346	938.0	572	401,228	630.8	636	153,104	558.2	274
Sept.	257,302	593.5	434	714,616	1,788.7	400	374,846	1,810.5	207
Oct.	14,377	79.3	181	98,072	401.7	244	-------	-------	---
Nov.	73,946	105.7	700	------	-----	---	-------	-------	---
Dec.	9,650	21.5	449	------	-----	---	-------	-------	---
Total[1]	1,179,261	2,144.0	550	1,369,727	3,146.2	435	680,542	2,616.2	260
Total[2]	1,068,000	2,144.0	498	1,413,000	3,146.2	449	925,000	[3]	

[1] Based on catches from vessel logs (incomplete for 1979).

[2] Based on statistics from landings.

[3] Total effort for 1979 not available.

Table 2. Minimum Trawlable Biomass - 1979 Research

Hopedale Channel

Stratum	Depth (m.)	Area (Sq. n. mi.)	No. Sets	Biomass (m. tons)
101	165-201	61.3	1	1
102	202-238	48.7	2	67
103	239-274	44.4	2	340
104	275-311	38.8	2	53
105	312-348	38.8	2	118
106	349-384	40.7	2	340
107	385-421	37.9	2	724
108	422-457	39.3	2	586
109	458-494	41.6	2	1,880
110	495-530	109.9	2	1,995
111-113	>530	51.5	4	1,911
205	312-348	174.0	2	62
206	349-384	134.7	2	731
207	385-421	95.0	3	12
208	422-457	147.8	3	2,130
209	458-494	161.9	2	45
210	495-530	168.0	3	23
211	531-567	168.4	3	129
212	568-603	163.3	2	16
305	312-348	30.4	2	12
306	349-384	23.4	2	79
307	385-421	18.7	2	143
308	422-457	18.3	2	99
309	458-494	18.7	1	1
310+311	495-567	55.2	2	6
312	568-603	37.9	2	2
313+213 +314	>603	299.9	1	15
Total		2,268.5	57	11,520

Table 3. Minimum Trawlable Biomass - 1979 Research

Cartwright Channel				
Stratum	Depth (m)	Area (Sq. n. mi.)	No. Sets	Biomass (m. tons)
5	312-348	83.7	3	14
6	349-384	31.0	3	19
7	385-421	34.2	4	37
8	422-457	36.5	3	136
9	458-494	59.7	4	718
10	495-530	88.8	4	568
11	531-567	25.0	1	614
Total		358.9	22	2106

Table 4. Mimimum Trawlable Biomass - 1979 Research

Stratum	Depth (m.)	Area (Sq. n. mi.)	No. Sets	Biomass (m. tons)
		Hawke Channel		
105	341-380	200.0	1	3
204	301-340	50.9	2	17
205	341-380	64.2	2	93
206+106	381-420	200.0	4	526
207	421-460	62.3	3	208
208+308	461-500	113.2	3	340
209	501-540	145.3	2	309
505	341-380	62.3	1	100
506	381-420	77.4	1	197
507	421-460	81.1	2	11
509	501-540	209.4	1	224
608+508	461-500	262.3	1	401
Total		1,528.4	23	2,429

Table 5. Conditions F relative to $F_{0.1}$ from yield per recruit calculations under options of d and M .

d	Z'	Z	M	F	$F_{0.1}$
3.0	0.46	1.38	0.7	0.68	0.90
			1.5	----	2.60
3.5	0.46	1.61	0.7	0.91	0.75
			1.5	0.11	2.10
4.0	0.46	1.84	0.7	1.14	0.60
			1.5	0.34	2.10

d = annual increase in length (mm)

Z' = instantaneous total mortality per mm

Z = instantaneous total mortality

M = instantaneous natural mortality

F = instantaneous fishing mortality

$F_{0.1}$ = F for a given method of fishing for which an increase in catch for a small increase in F is one-tenth the increase in catch for the same increase in F from zero.

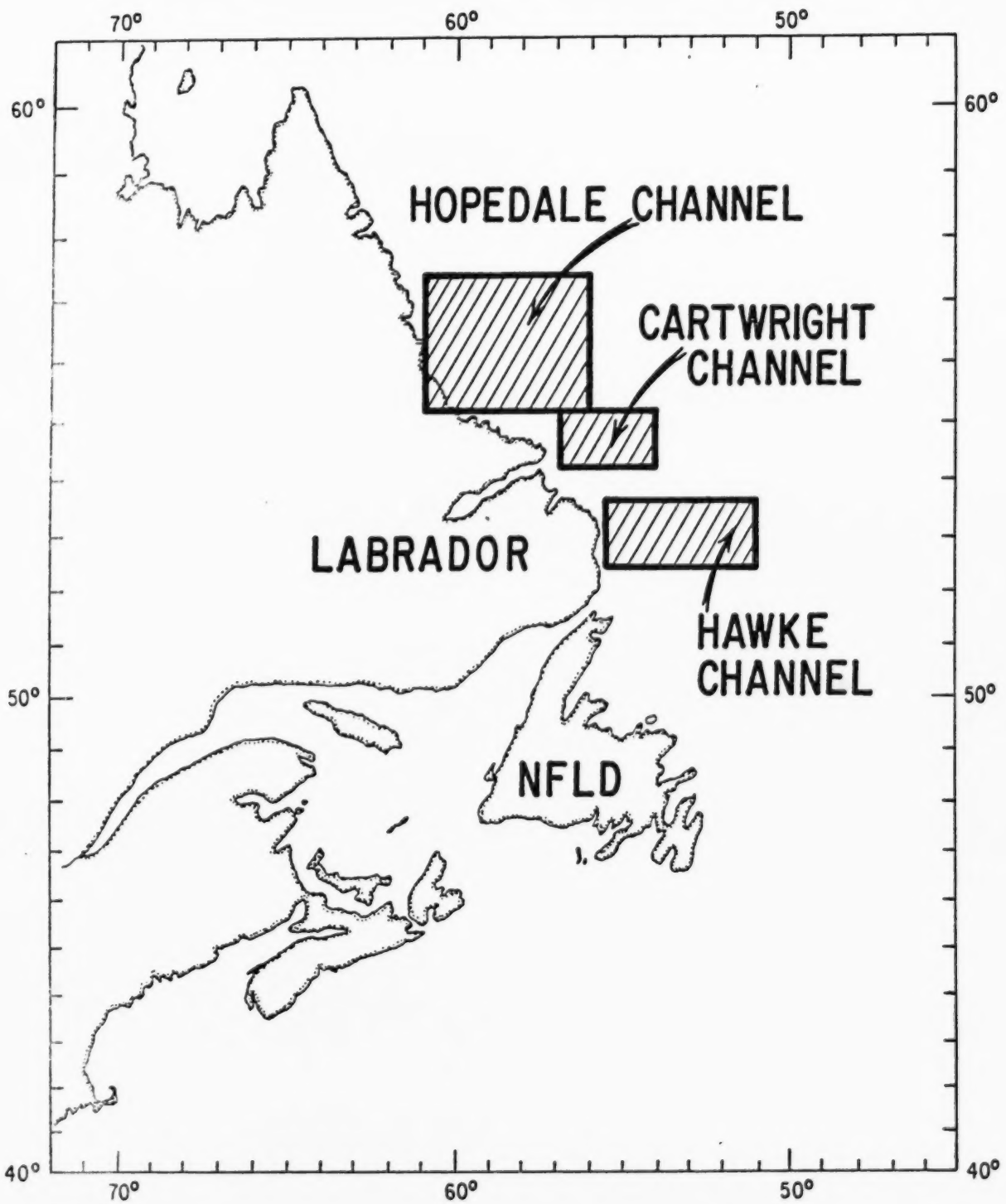

Fig. 1. Areas of principal shrimp concentrations in Divisions 2H and 2J.

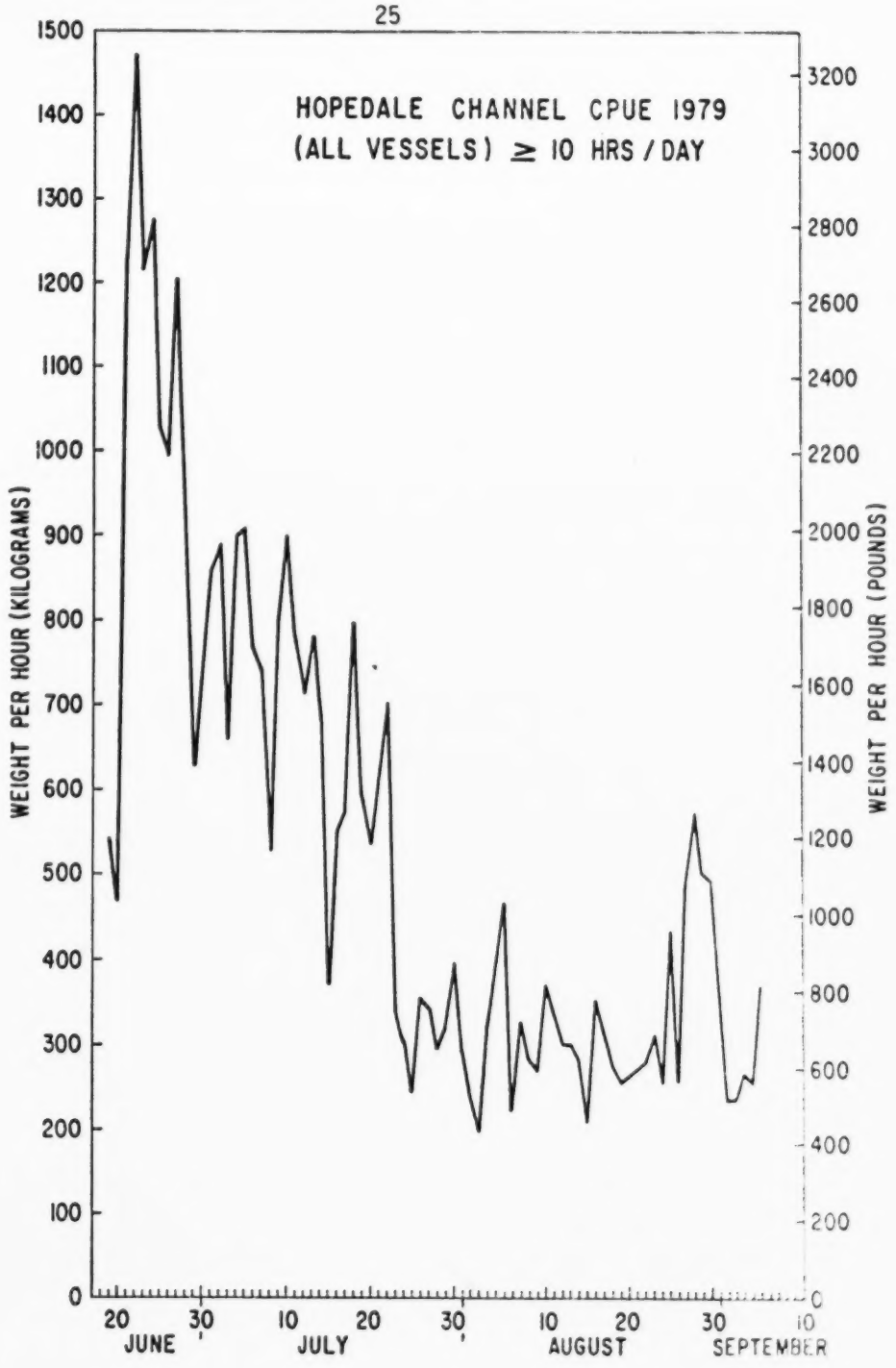

Fig. 2. Catch per unit effort - 1979.

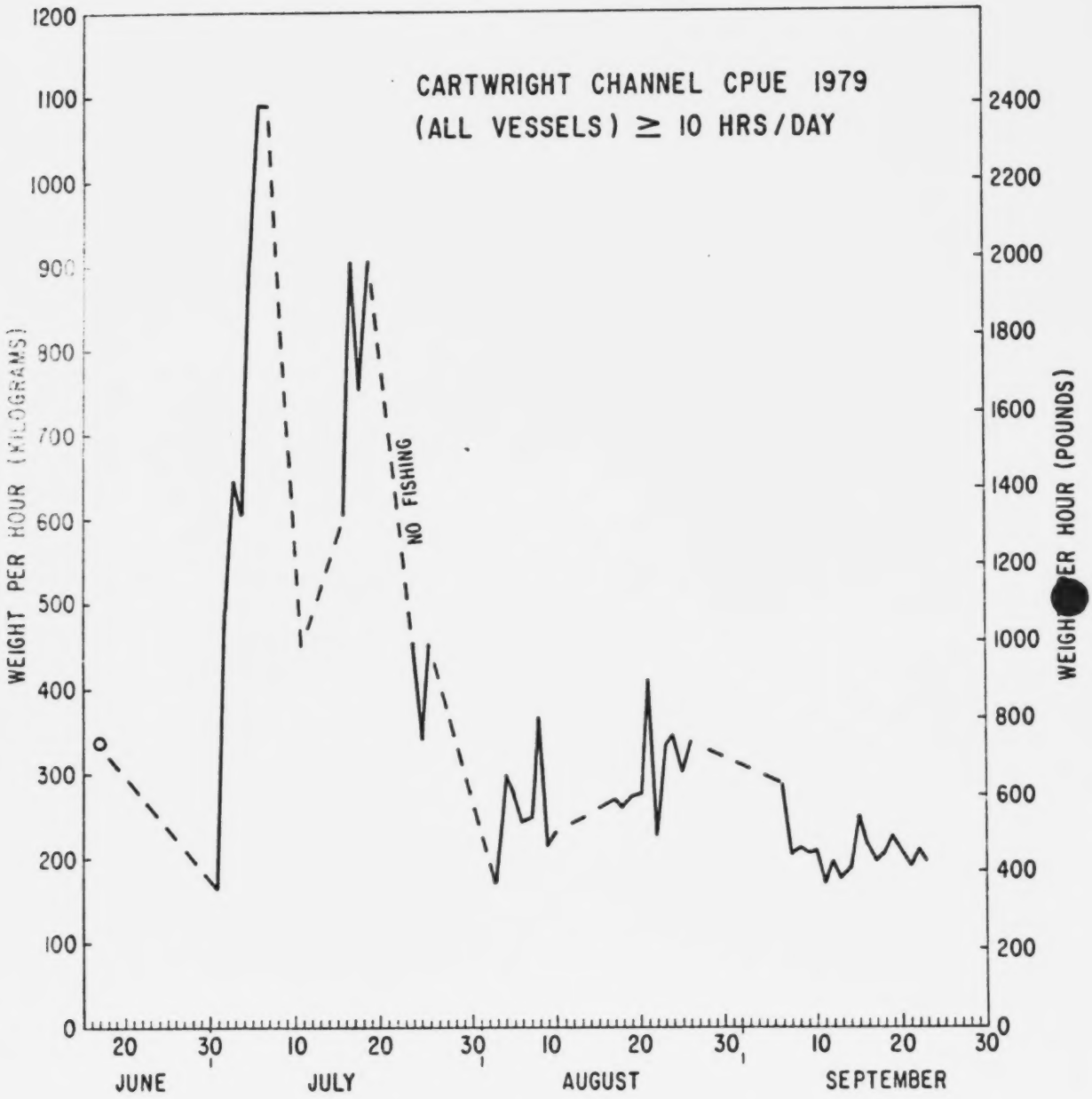

Fig. 3. Catch per unit effort - 1979.

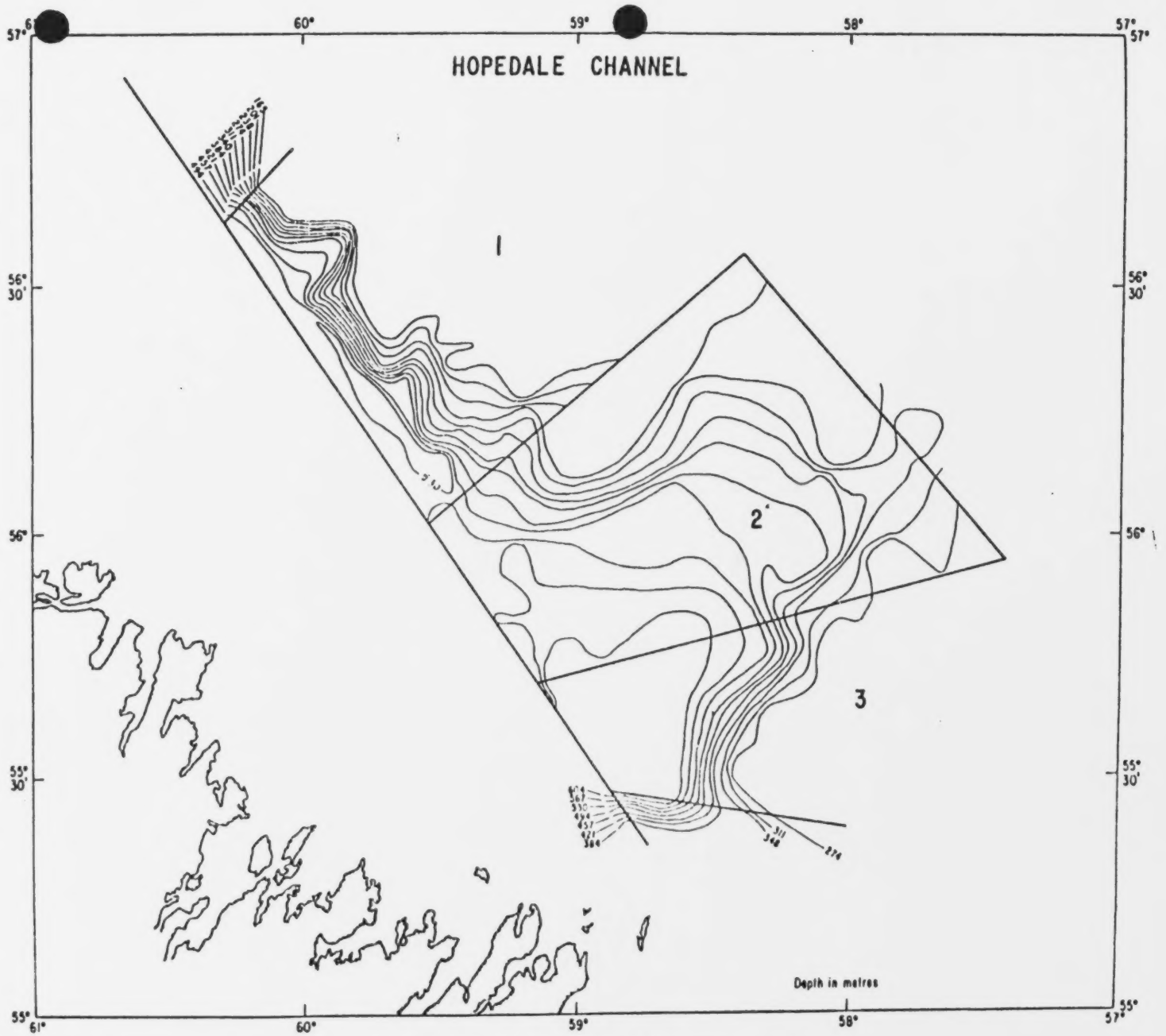

Fig. 4. Stratification of the Hopedale Channel.

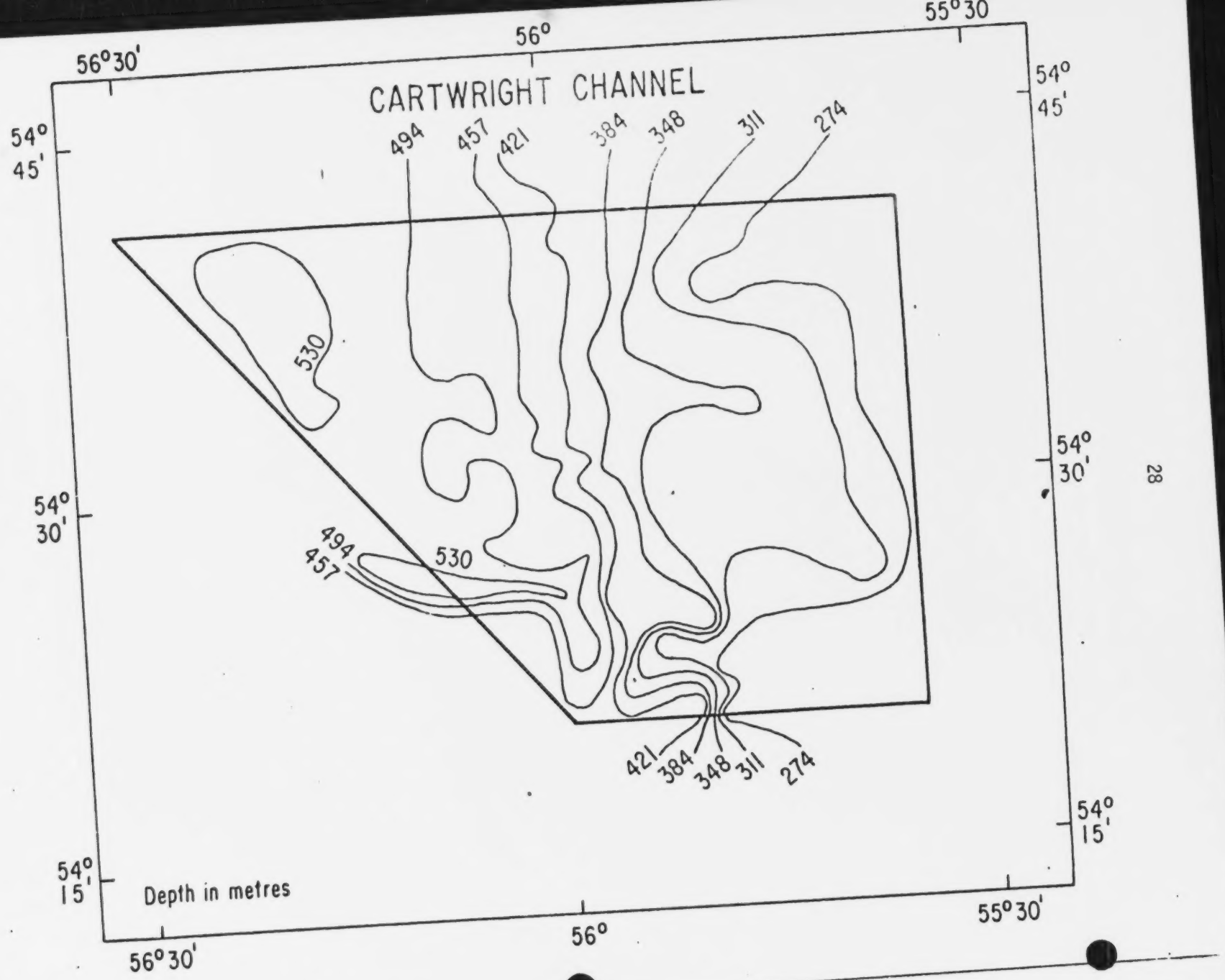

Fig. 5. Stratification of the Cartwright Channel.

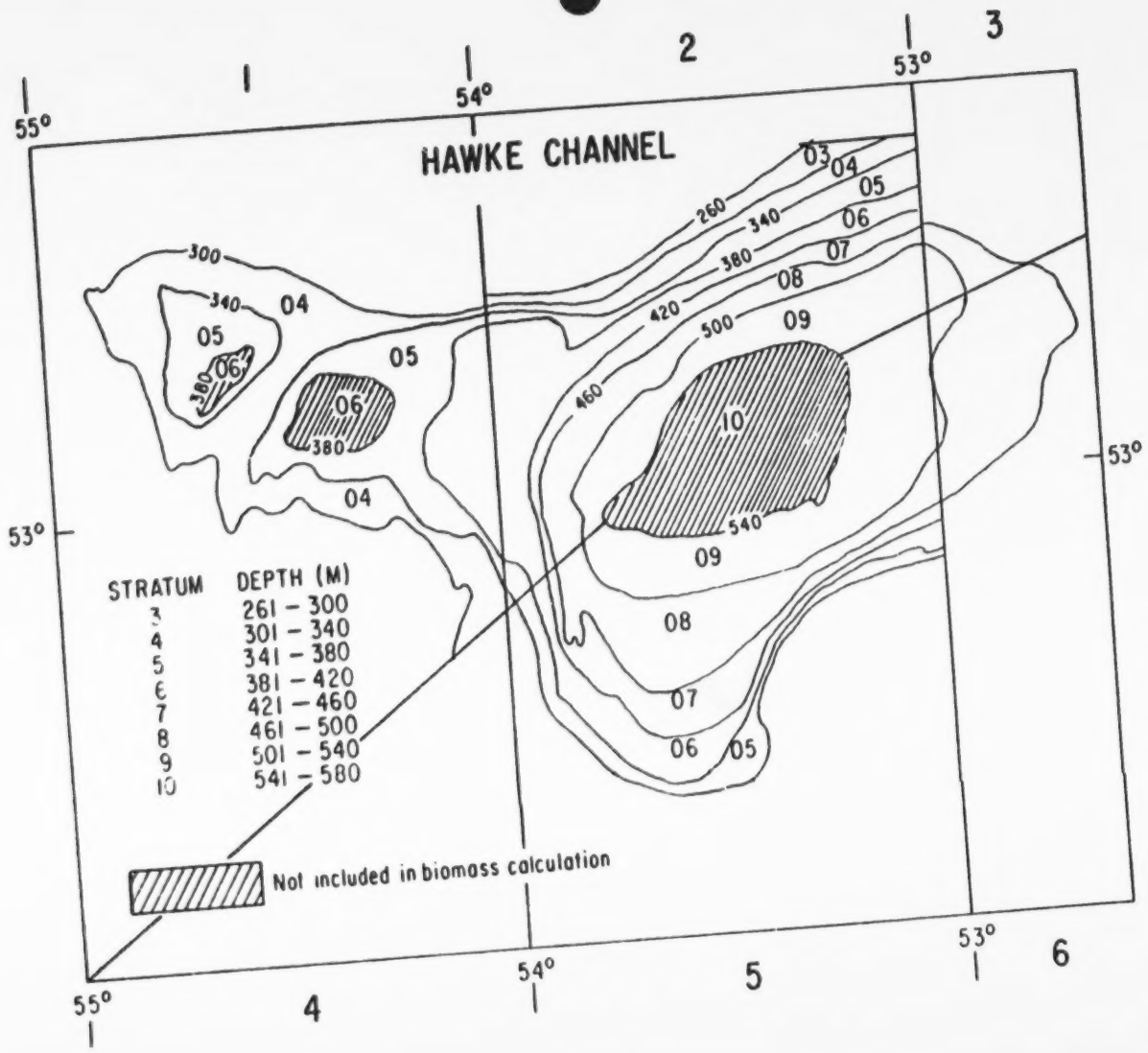

Fig. 6. Stratification of the Hawke Channel.

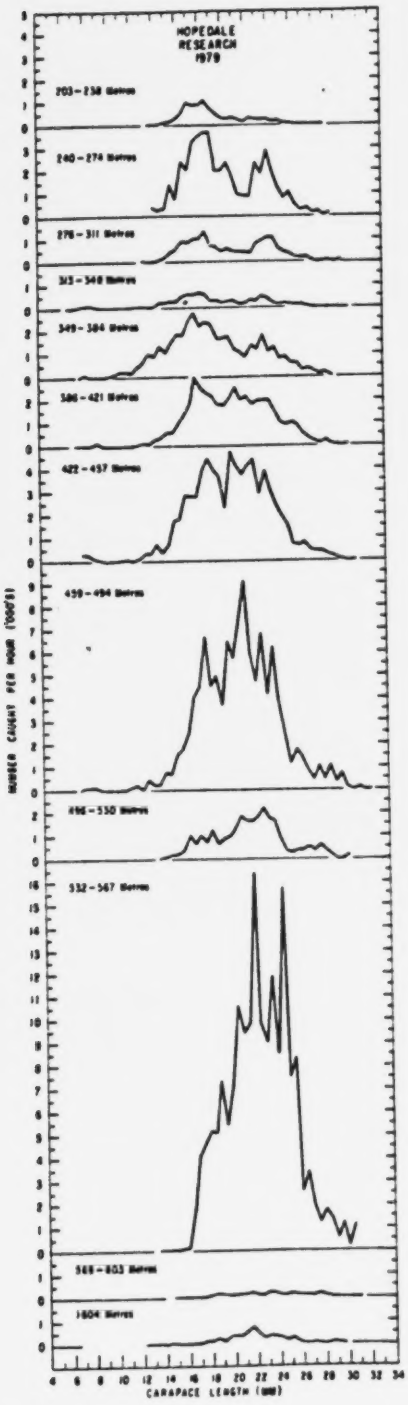

Fig. 7. Research length frequencies - 1979

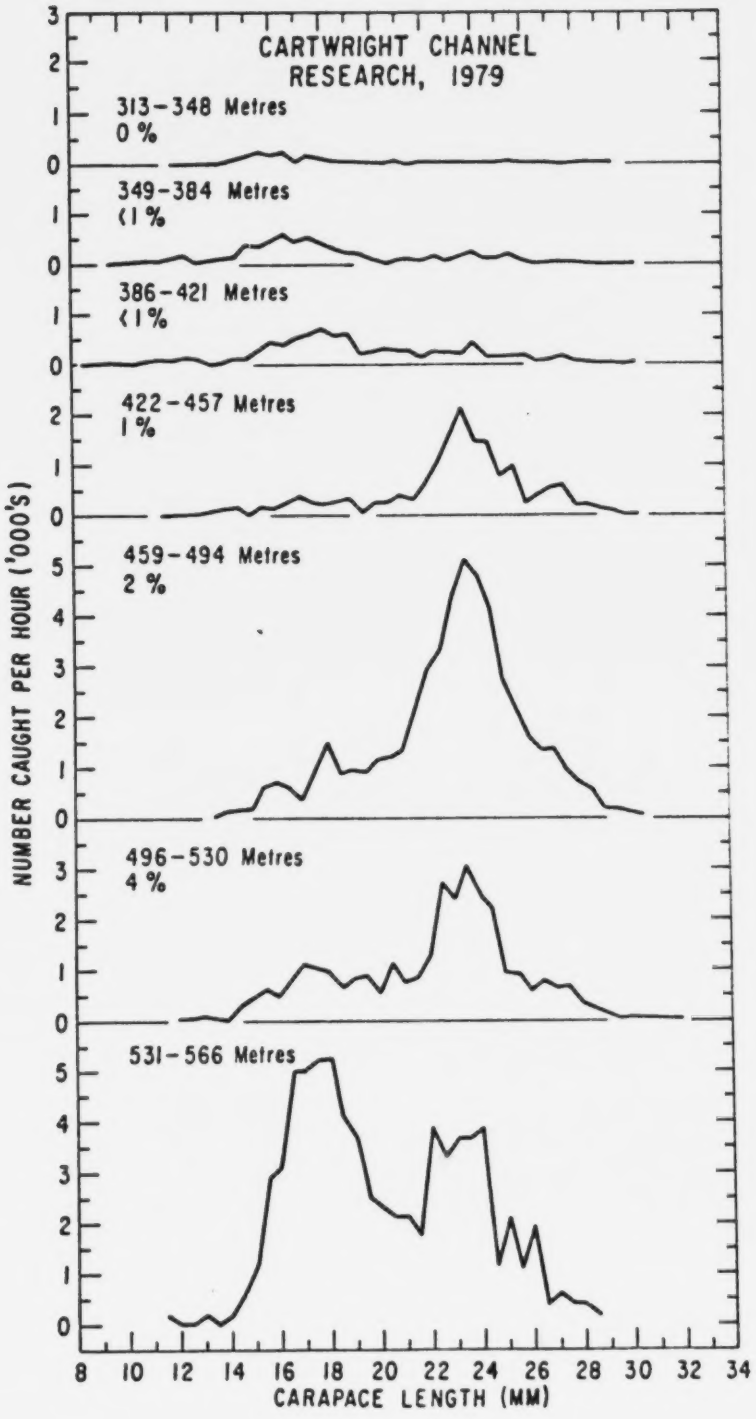

Fig. 8. Research length frequencies - July 1979, (% ovigerous indicated)

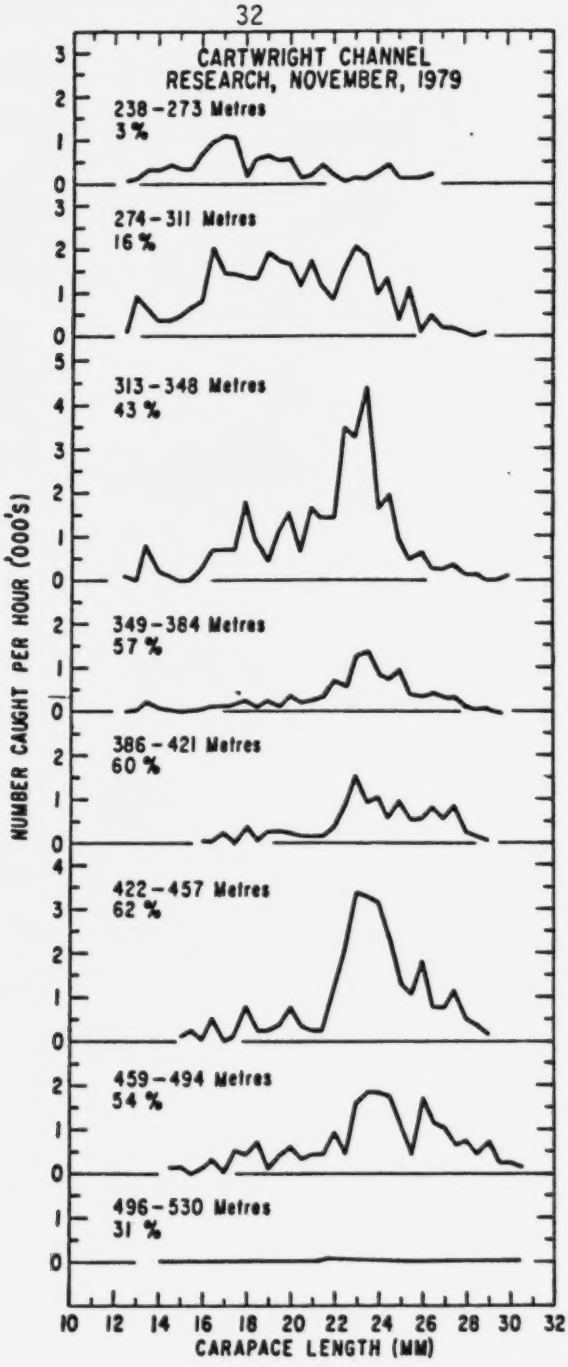

Fig. 9. Research length frequencies - November 1979. (% ovigerous indicated)

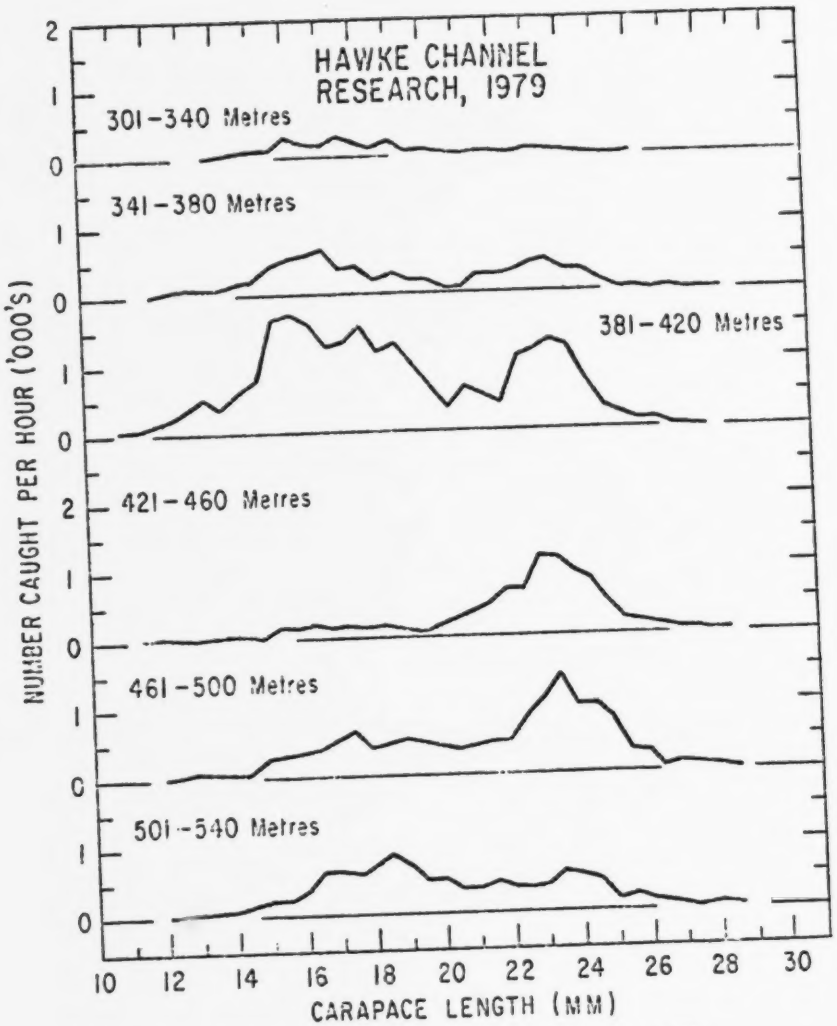

Fig. 10. Research length frequencies - 1979

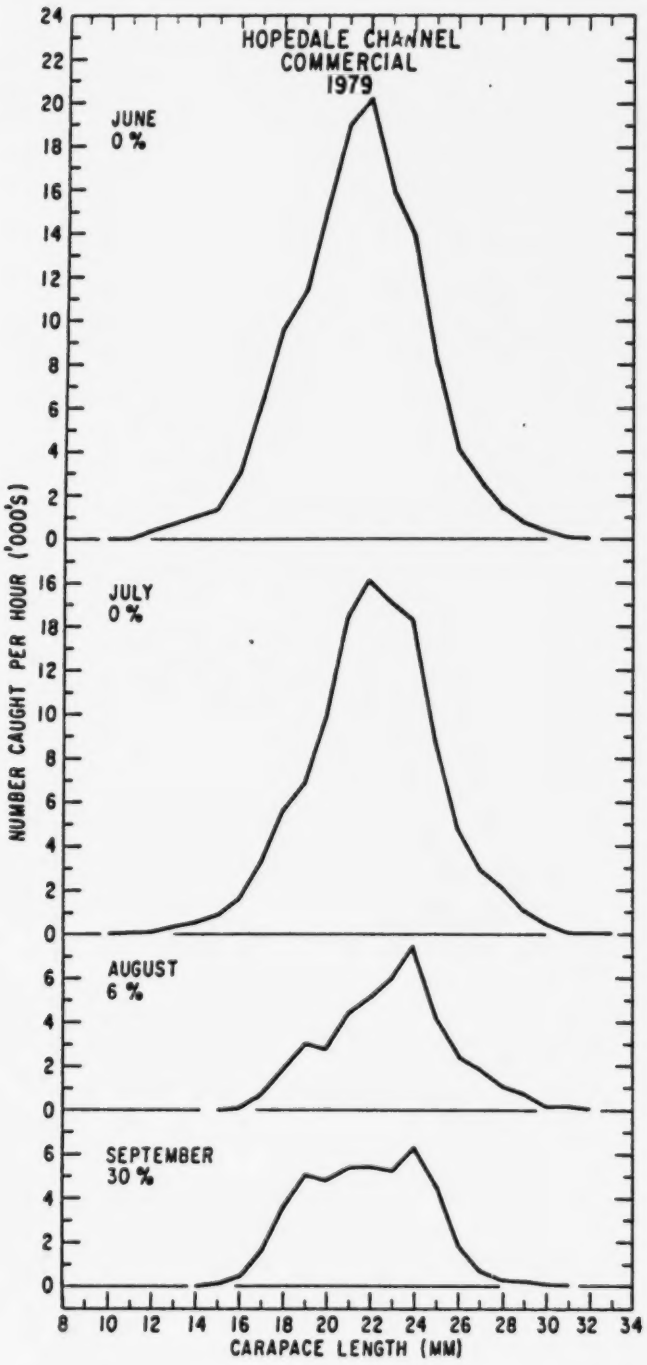

Fig. 11. Commercial length frequencies - 1979.
(% ovigerous indicated)

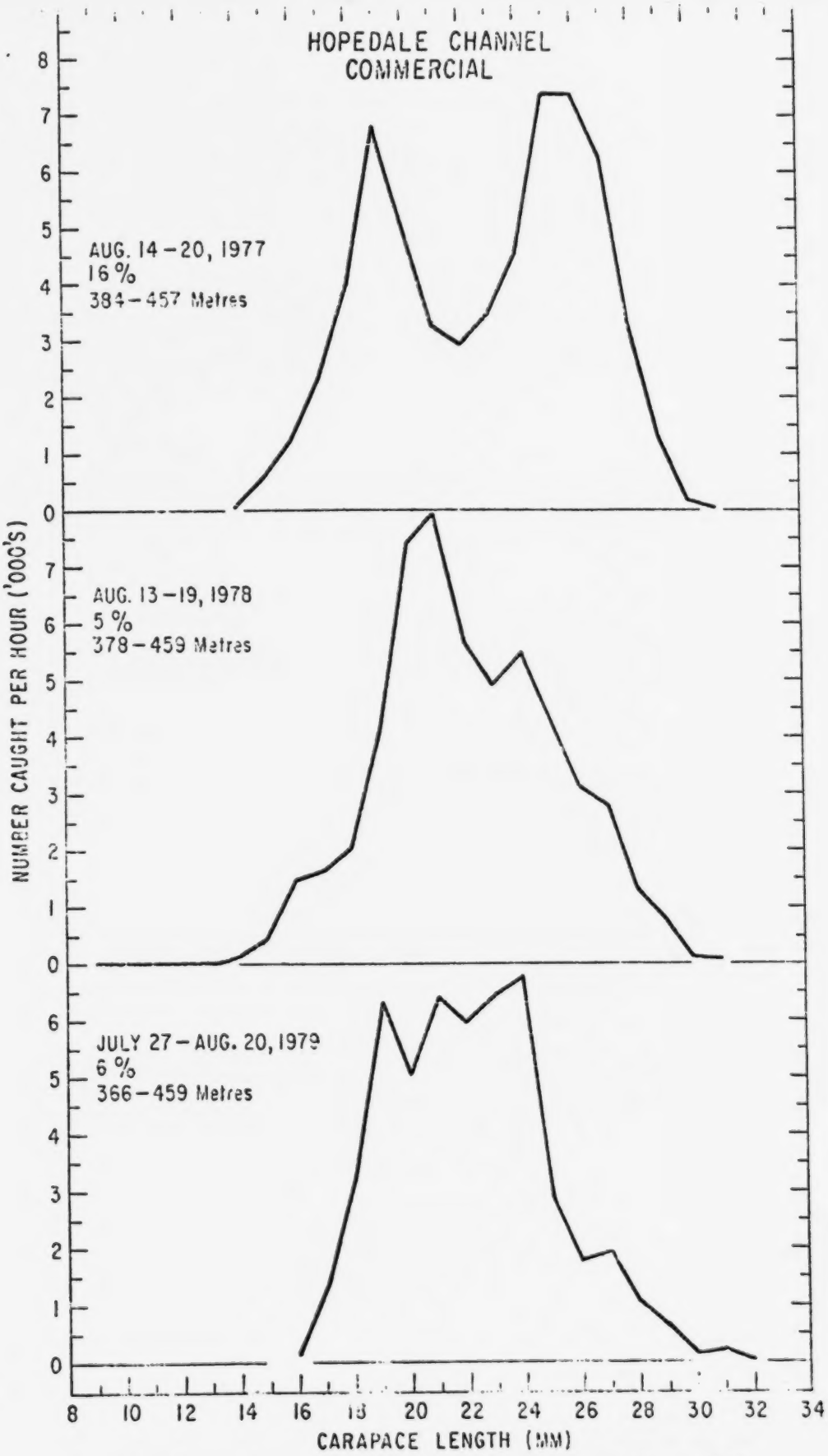

Fig. 12. Comparison of length distributions, 1977 to 1979. (% ovigerous indicated)

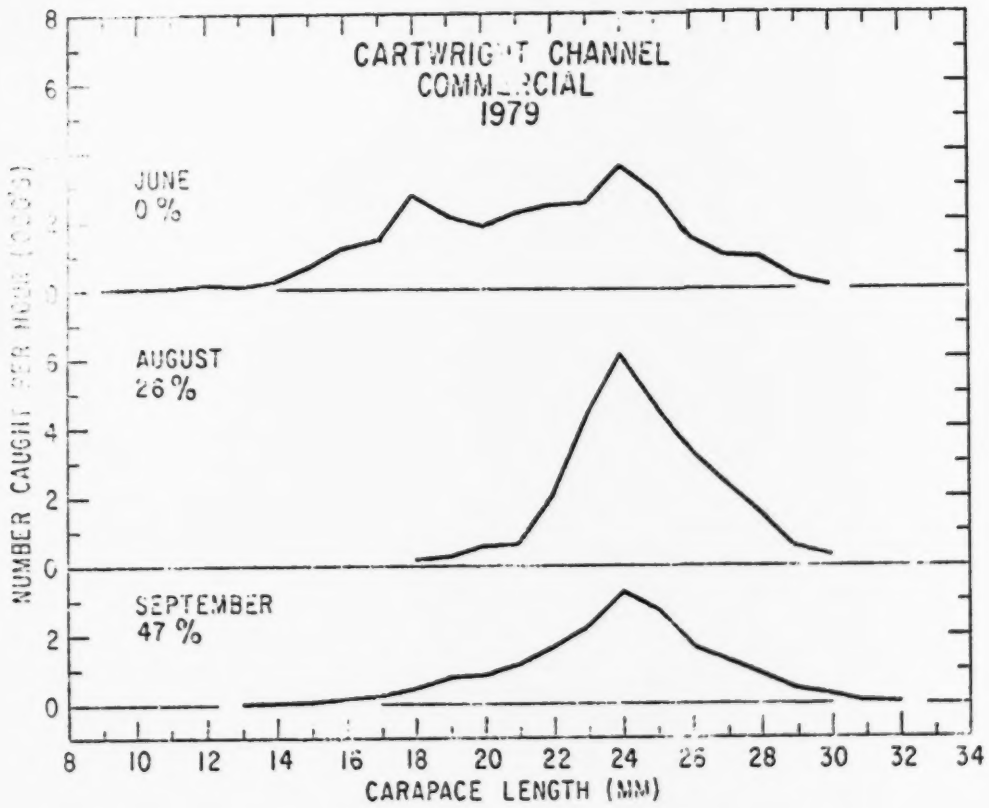

Fig. 13. Commercial length frequencies - 1979. (% ovigerous indicated)

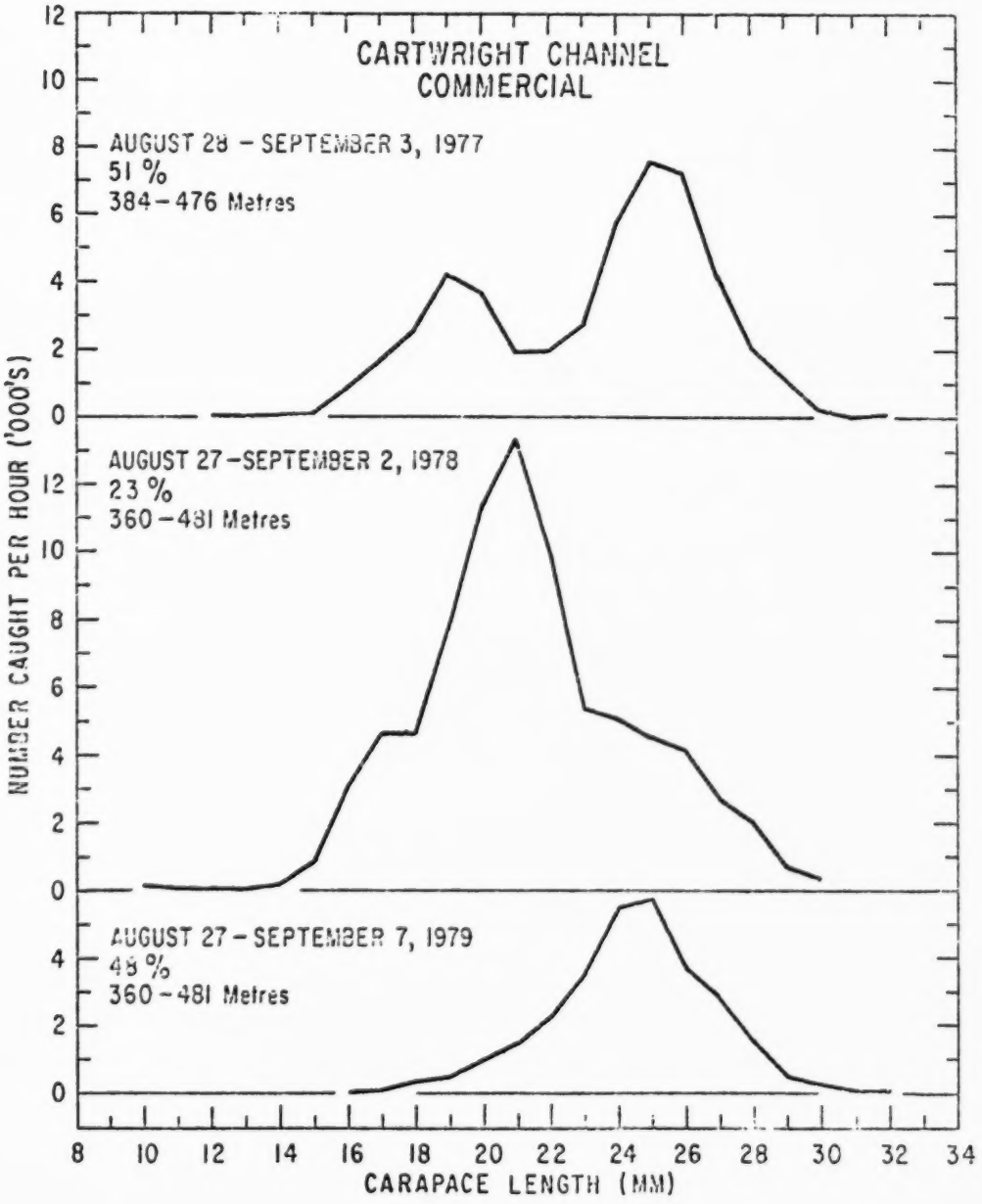

Fig. 14. Comparison of length distributions, 1977 to 1979.

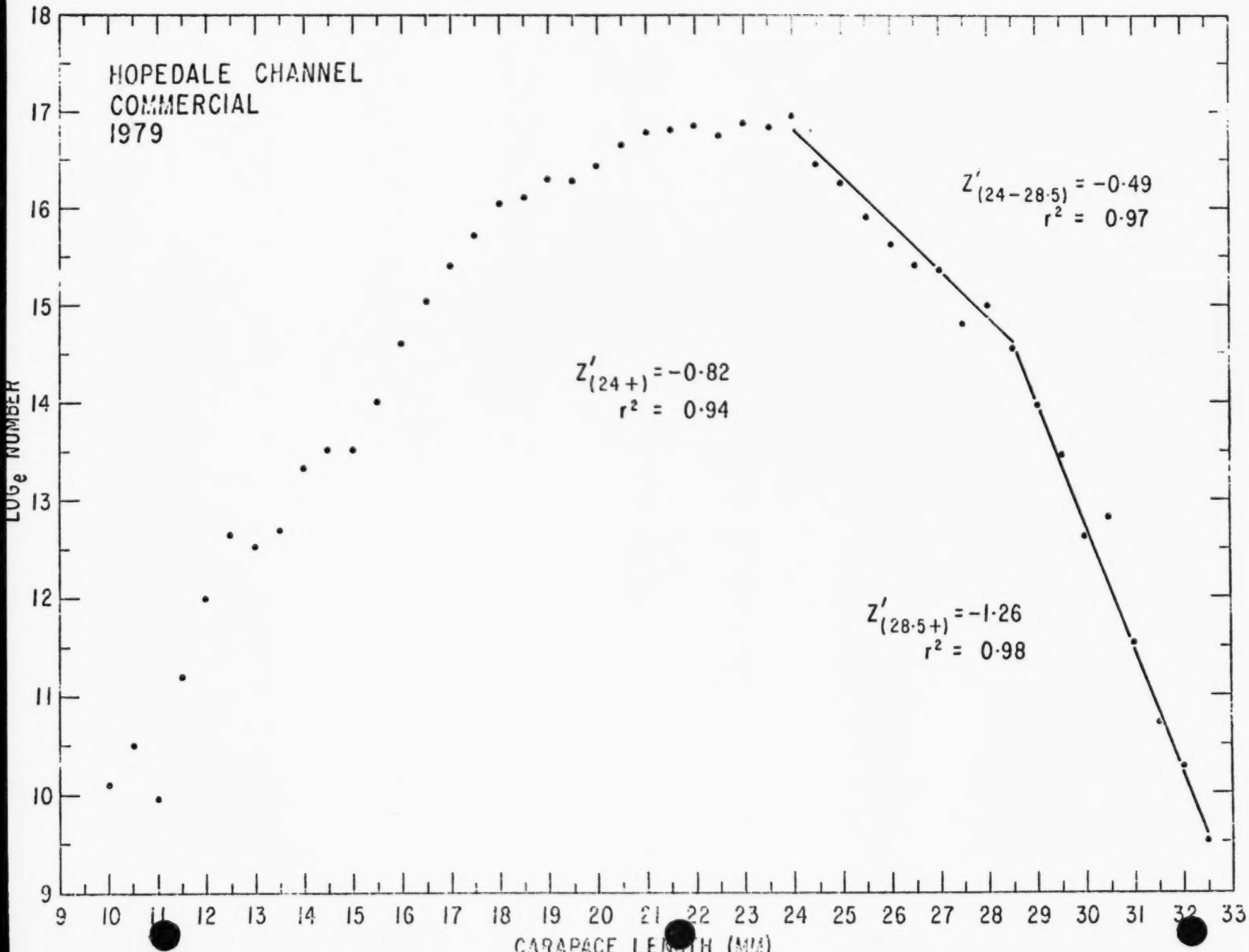

Fig. 15. Catch curve - 1979 commercial

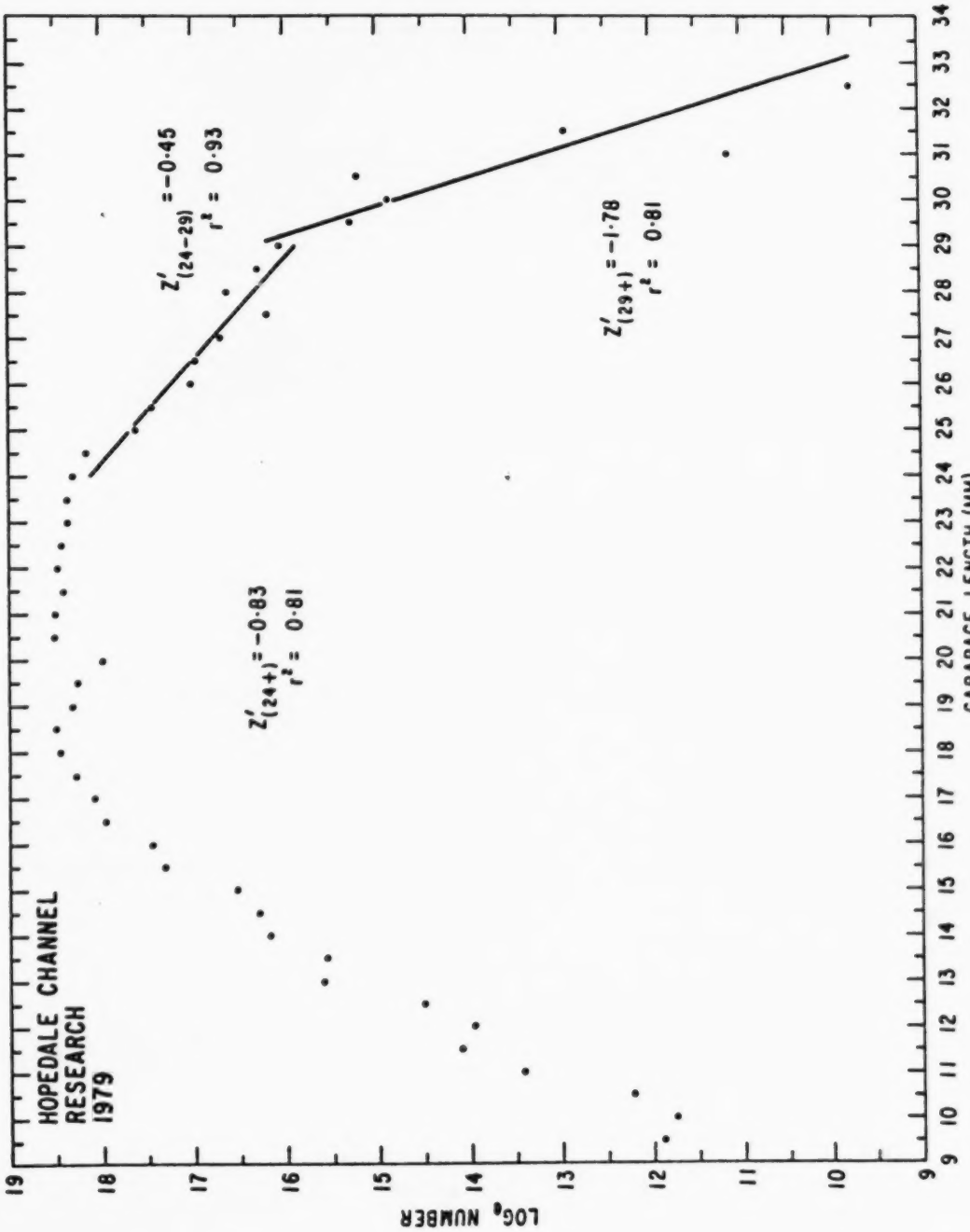

Fig. 16. Biomass curve - 1979 research

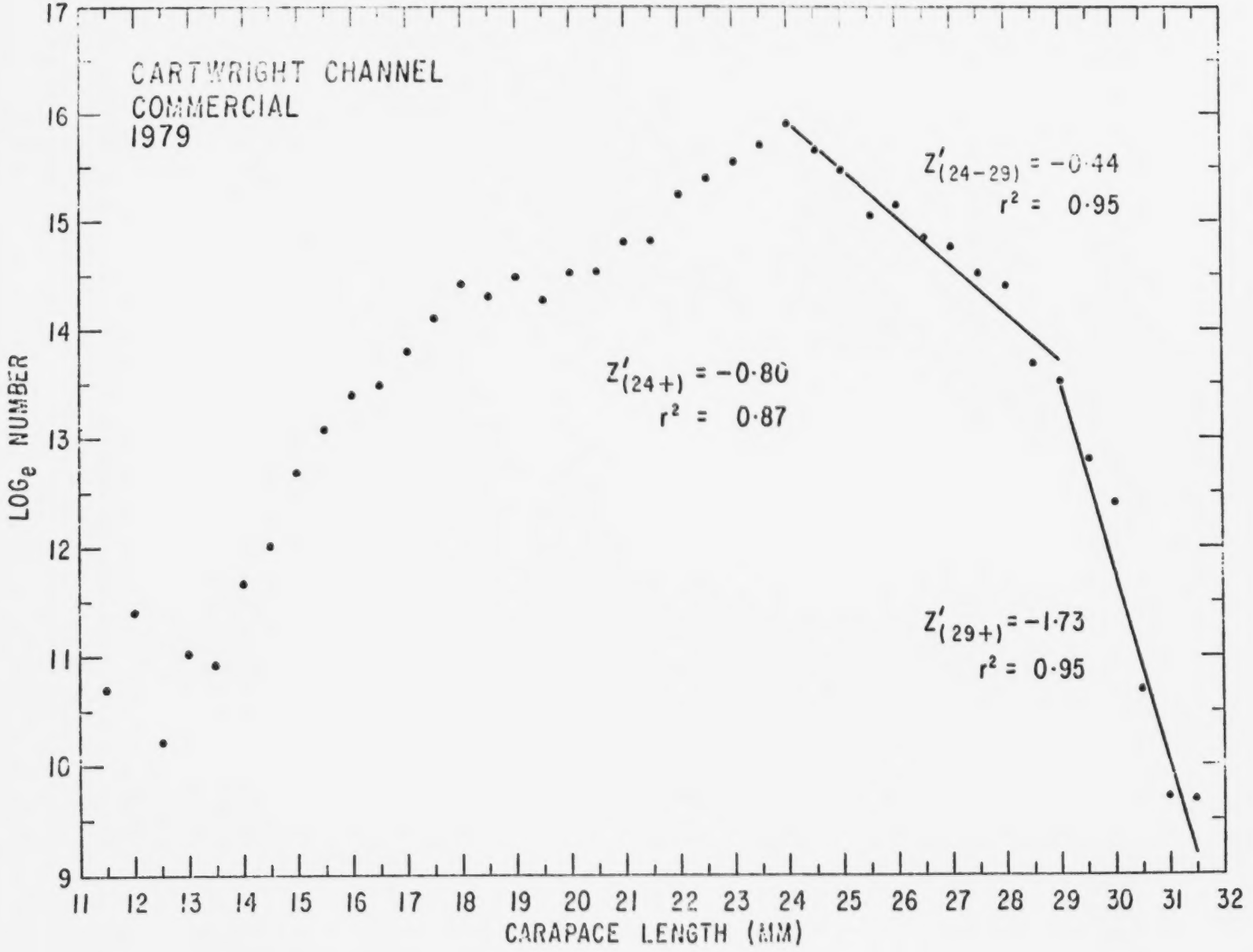

Fig. 17. Catch curve - 1979 commercial

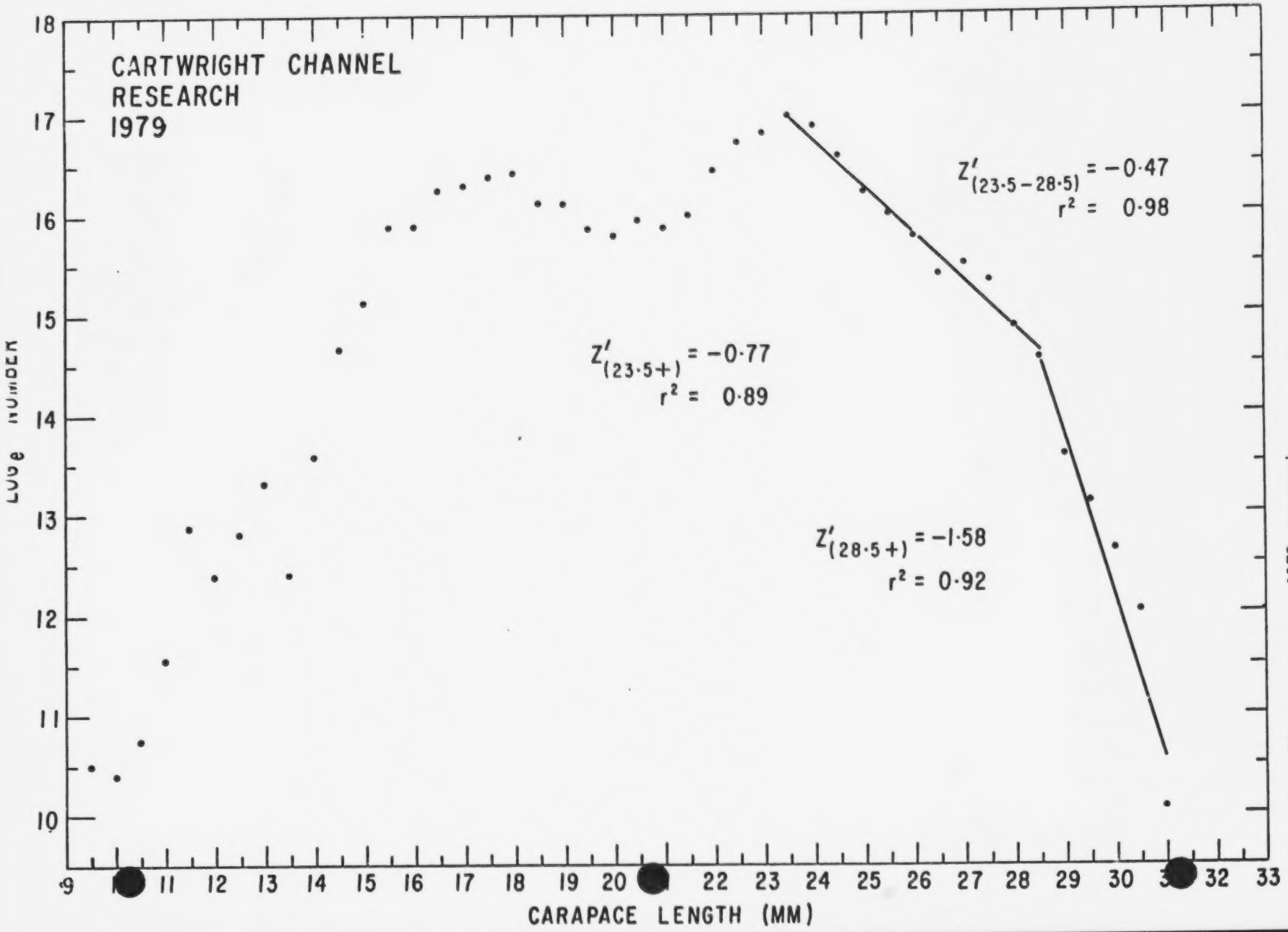

Fig. 18. Biomass curve. 1979 research

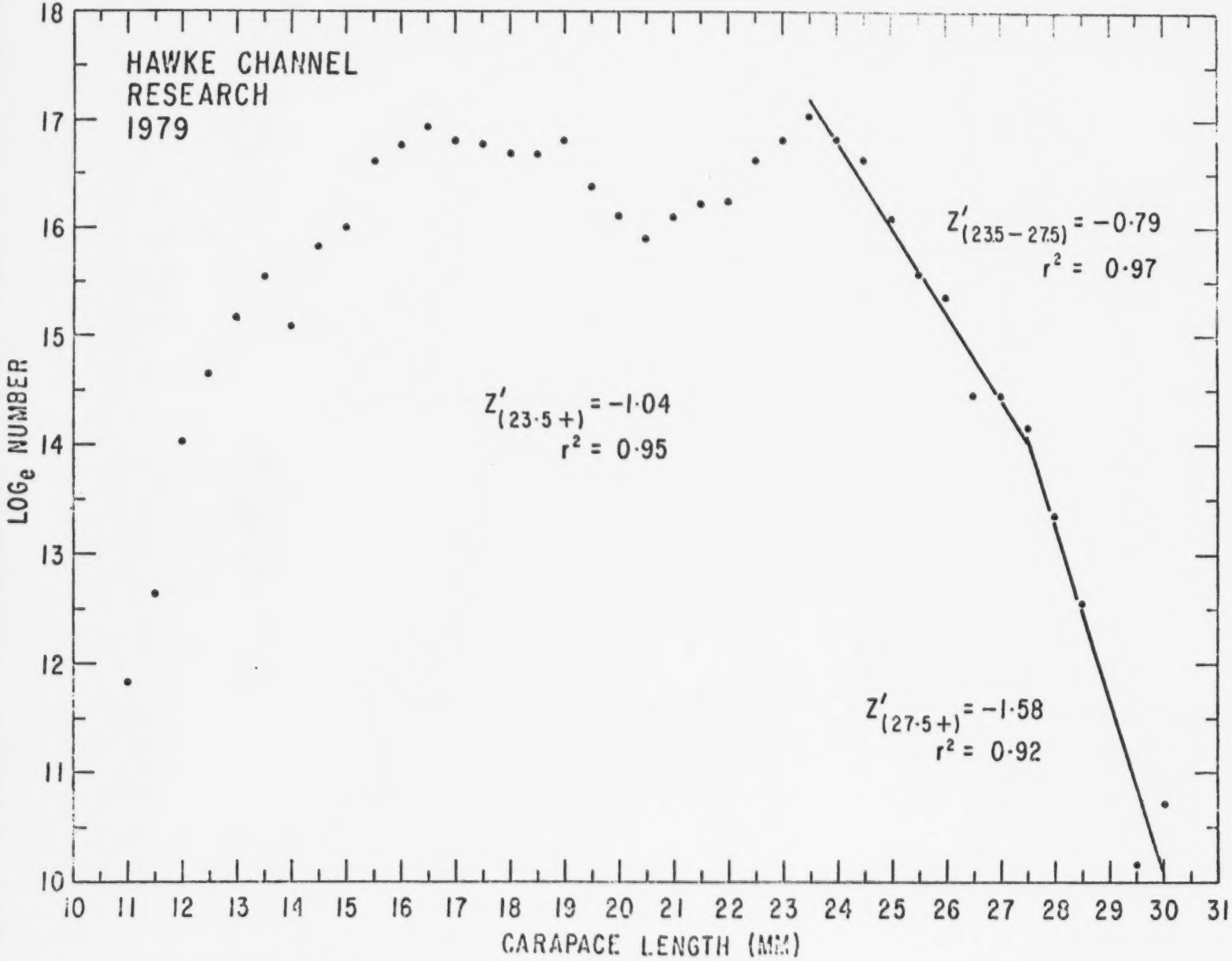

Fig. 19. Biomass curve - 1979 Research

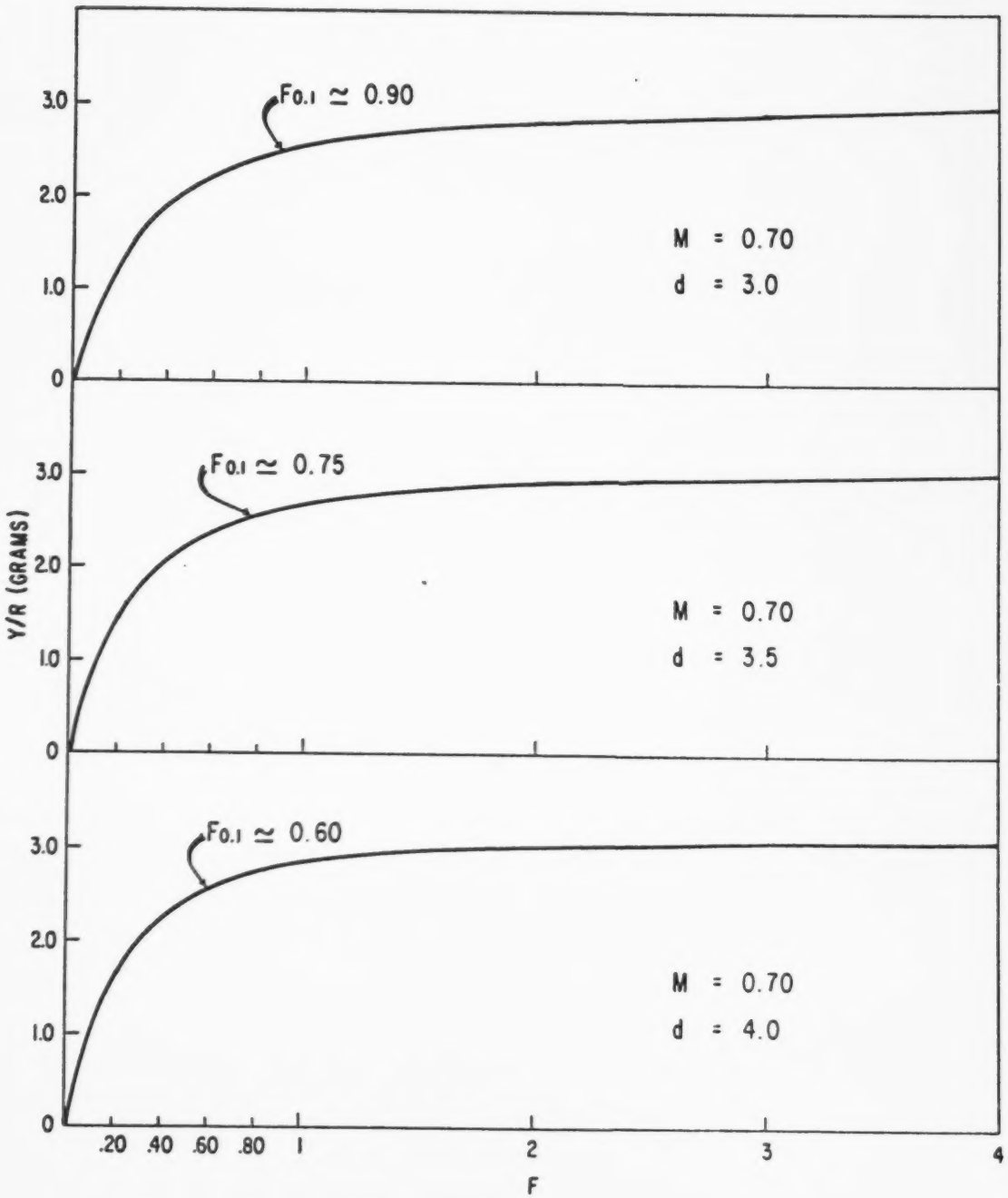

Fig. 20. Yield per recruit curves

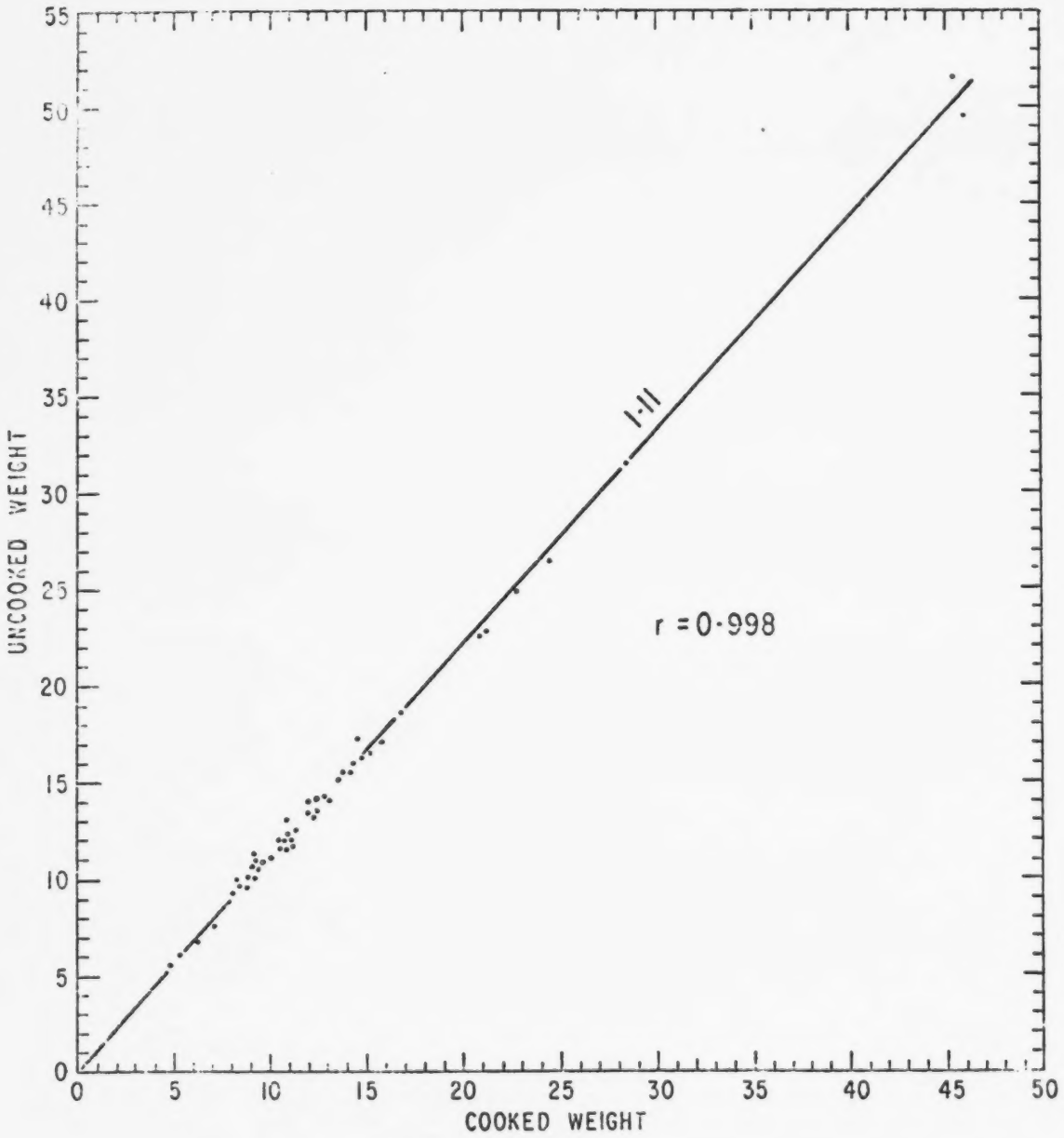

Fig. 21. Regression (through the origin) of uncooked weight vs cooked weight.